

# ***Review of the Department of Energy's Laboratory Directed Research and Development Program***

**Report of the External  
Members of the Laboratory  
Operations Board**

**January 27, 2000**

**Laboratory Operations Board  
U.S. Department of Energy**





**Secretary of Energy Advisory Board**  
Washington, DC 20585

February 2, 2000

Mr. Andrew Athy  
Chairman, Secretary of Energy Advisory Board  
c/o O'Neill, Athy & Casey, PC  
1310 19<sup>th</sup> Street, NW 20036  
Washington, D.C. 20036

Dear Mr. Athy:

With this letter I am transmitting to you a report on the Department of Energy's Laboratory Directed Research and Development program. The report was prepared in response to a request by the Under Secretary, Dr. Ernest Moniz. He asked the external members of the Laboratory Operations Board to form a Working Group of external members to assess the continued need for the program. The external members of the Laboratory Operations Board reviewed and approved the report on January 27, 2000.

Dr. Paul Fleury, Dean of the School of Engineering, University of New Mexico, served as the Working Group Chair. The Working Group reviewed a number of background documents that established the philosophy underpinning the need for discretionary research and development at the Department of Energy's multi-program laboratories. The Working Group used its own extensive experience in private industry as well as information obtained from other sources to serve as a baseline of industry best practices in assessing the Department's program.

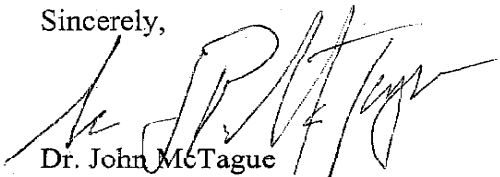
They determined early on that the focus should be on discretionary research and development in the weapons laboratories and that supported by Environmental Management. These activities were most seriously affected by the recent reductions authorized by Congress. The FY 2000 authorization limited the amount the Laboratories could assess at four percent, down from six percent, of each laboratory's total operating budget. The legislation prohibited the use of Environmental Management funds for this activity.

The science laboratories have traditionally funded their Laboratory Directed Research and Development programs at below the four percent level. While the Working Group believes that those programs are equally important, the report concentrates on the programs most affected by the authorized reduction.

Mr. Andrew Athy  
February 2, 2000  
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The Working Group and the Laboratory Operations Board appreciate the opportunity to work on this important issue. Thank you for your consideration.

Sincerely,

A handwritten signature in black ink, appearing to read "Dr. John McTague", written over the printed name.

Dr. John McTague  
Co-Chair, Laboratory Operations Board

Enclosure (1)

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# LABORATORY OPERATIONS BOARD

## External Members Working Group On LDRD Programs

Dr. Paul Fleury [**Working Group Chair**]  
Dean, School of Engineering  
University of New Mexico  
Albuquerque, New Mexico

Dr. John Armstrong  
Vice President (Retired), Science and Technology  
IBM  
Amherst, Massachusetts

Dr. Alexander MacLachlan  
Senior Vice President and Chief  
Technical Officer (Retired)  
E. I. du Pont de Nemours and Company  
Wilmington, Delaware

Dr. John McTague, **LOB** Co-Chair  
Vice President, Technical Affairs (Retired)  
Ford Motor Company  
Montecito, California



# **EXECUTIVE SUMMARY**

## **Background and Charge**

For FY 2000, the U.S. Congress drastically reduced the Laboratory Directed Research and Development (LDRD) appropriation for the Department of Energy's national multi-program laboratories. The Congressional action eliminated entirely funds authorized for Environmental Management programs from the LDRD funding base and reduced the maximum LDRD expenditure from all other sources by one third, from 6 percent to 4 percent of a laboratory's total operating budget, including non-departmentally funded work.

The threat that the reduction in LDRD funding poses to future mission execution for the Department of Energy and the laboratories in the areas of science, National Defense and environmental management has caused serious concern at both the laboratories and the Department. At the September 1999 LOB meeting, prior to the Congressional appropriation action in October, the Under Secretary asked the Laboratory Operations Board to form a working group of external members. The purpose of the working group was to review the LDRD program and report on the value, quality, nature of oversight, and continued need to support the program.

The Working Group obtained information on the types of research projects funded by LDRD and the processes in place to manage the program, as well as on the metrics for success and long range impacts of LDRD on DOE missions

The Working Group did an overall benchmarking with private, high technology industries in the United States in terms of the investment in and metrics for basic research. The Industrial Research Institute and working group members who had held positions as research executive managers at major U.S. corporations provided information in support of this effort. The Working Group compared levels of investment in basic research as a fraction of total research and development made by industry, the Department of Defense and the Department of Energy

## **Findings**

We find that

- the need and concept for the LDRD program is sound and congruent with industry best practice;
- LDRD type programs have historically enabled the Department to execute future mission responsibilities;
- LDRD programs are vital in recruiting, retaining and integrating the best scientific talent into the laboratories and their mission programs;

- LDRD programs are highly effective in generating scientific discoveries, patents, publications and awards;
- the size of the LDRD program at 6 percent is marginally acceptable at best; at 4 percent it is well below threshold for maintaining scientific excellence;
- LDRD is well managed with participation from HQ, the labs and the field;
- accusations of mismanagement are few and amount to questions at the 1 percent level of total LDRD funding;
- flexibility in planning research projects is especially crucial for the Defense Program laboratories to execute their missions;
- present cuts in LDRD constitute a threat to National Security, and to the ability of the laboratories to attract and retain needed scientific talent;
- elimination of Environmental Management from participation in the LDRD program weakens the nation's clean up effort substantially
- combined with the new semi autonomous National Nuclear Security Administration within the Department of Energy, the reduction in LDRD threatens the level and quality of scientific interactions within and among the laboratories.

## **Recommendations**

- The Congress should immediately restore the LDRD program at the DOE multi-program laboratories to at least the 6 percent level and should restore Environmental Management programs to the LDRD base.
- The Department of Energy should simplify LDRD oversight and approval processes to be more consistent across the department and with industry best practices.
- In the design and implementation of the proposed DOE reorganization careful consideration should be given to ensuring continued support for the defense science base and the continued ability of the LDRD program to serve all aspects of the laboratories' programs.

# **Review of the Department of Energy's Laboratory Directed Research and Development Program**

## **1. Background and Working Group Charge**

The leadership of every organization bears the responsibility for ensuring that the organization delivers against its mission, in both the short and long terms. The defense and well being of the United States are principal missions of the United States government in general and of the Defense and Energy Departments in particular. More specifically, the Department of Energy laboratories bear a substantial portion of the responsibility to ensure that the nation's nuclear weapons systems and stockpile as well as its leadership in basic science will remain sound in the coming decades. In addition responsibility for clean ups of nuclear and many chemical waste sites rests largely with DOE. These are technologically intensive missions, and as with any mission of this type, the role of research and development is critical.

The DOE laboratories have developed into the world's finest for the design, maintenance and stewardship of nuclear weapons on the one hand and for the pursuit of large, facility-based fundamental research on the other. Within the Department, the Office of Defense Programs and the Office of Science generally carry the major responsibility for those arenas. The Congress and the Department have long recognized the dual importance of meeting the mission today and investing to ensure meeting it in the future. Within this framework the Department and the Congress have supported, through a succession of mechanisms, flexible investment in research that is not strictly programmatic in nature. The formal authority for this research is granted by Congress and directed by DOE Order 413.2 and is known as Laboratory Directed Research and Development (LDRD).

With DOE O 413.2, the LDRD program was most recently re-authorized on March 5, 1997 [8]. It followed closely upon its predecessor under order DOE 5000.4A. The National Defense Authorization Act for FY 1997 [Public Law 104-201] is the current authorizing legislation. Public Law 105-85 requires the Department of Energy to assess the LDRD program and to recommend to Congress the percent of funds that should be made available for LDRD.

The stated objectives of the LDRD program are:

- to maintain scientific and technical viability of the laboratories,
- to enhance the ability of the laboratories to address the Department's future missions,
- to foster creativity and stimulate exploration of forefront science and technology,
- to serve as a proving ground for new research, and
- to support high risk and potentially high value R&D.

The order lays out not only objectives, but also management practices and processes, prohibitions on use of funds, and responsibilities of the Department's Principal

Secretarial Offices, the laboratory management, and the operations offices. It contains reference to five federal acts spanning the history behind the current order. Finally, it establishes a maximum funding level for LDRD in each laboratory. The order states that the tax “shall not exceed 6 percent of the laboratory’s total operating budget, including non-departmental funded work, for the year plus an amount of capital equipment funds not to exceed 6 percent of its total capital equipment budget for the year.” For FY 1998, the total authorized LDRD funds exceeded \$250M across the nine multi-program laboratories in the Department.

Although not a new program in concept or even in execution, LDRD has continued to receive scrutiny from the Congress, the Office of Management and Budget, and the Department’s Office of the Inspector General. This scrutiny is in addition to the substantial and continuing review and oversight from within the laboratories and the Department of Energy. Over the past decade or more, such scrutiny has sometimes led to inappropriate appellations and accusations, such as, “walking around money for laboratory directors” and use of “creative accounting” to increase LDRD beyond the authorized limits.

Recently and most dramatically, the original House bill in the 106<sup>th</sup> Congress cut out the LDRD program entirely. It was partially restored [HR 2605] in conference to a 4 percent maximum--down from the previous and historical amount of 6 percent. In addition, the legislation forbade the taxing of Environmental Management programs in providing any funds for LDRD. This prohibition represented a further reduction in the total LDRD dollar support available for the laboratories, and has forced a 2/3 reduction in Idaho National Engineering and Environmental Laboratory’s LDRD program. This legislation has called into question the value and understanding as well as the very future of the LDRD program.

At the September 1999 meeting of the Laboratory Operations Board, the Under Secretary requested the external members to conduct an independent review of the Department’s LDRD program. The scope of this charge included a review of background documents, an examination of the philosophy behind LDRD, an assessment of the need for discretionary research and development at the multi-program laboratories, and an assessment of the current LDRD processes. The external members were asked to report on the utility of the program, the sufficiency of DOE oversight, the quality of the research, and opportunities for improvement.

A subcommittee of external members was formed [John Armstrong, Paul Fleury, Al MacLachlan, John McTague, and Laurie Keaton--staff]. The subcommittee examined over fifty government and industry reports on LDRD and industrial and government research. The Working Group enlisted the cooperation of laboratory and field and headquarters management. The Working Group interviewed dozens of people, visited the Lawrence Berkeley National Laboratory and the Sandia National Laboratory, and consulted with the Industrial Research Institute and four major industrial research laboratories on best industry practices for research and development management.

Numerous conference calls were convened between mid-October and mid-December during 1999. Paul Fleury met with the Defense Programs Laboratories LDRD Working Group [chaired by Gerald Green of Defense Programs] at Sandia on November 9, 1999. Each external LOB member who is serving on the LDRD committee is a former research director at a major industrial laboratory [IBM, Lucent, Dupont, and Ford]. Each contacted his respective laboratory for updates on the practice of research and development management and strategy at that particular laboratory. The Working Group requested and received direct input from several laboratory directors and their LDRD managers, reviewed several dozen documents and reports.

The committee also consulted Chuck Larson of the Industrial Research Institute, who provided data on industry wide trends and practices. Finally, following a status report briefing to the Laboratory Operations Board at its December 2, 1999, meeting at the Lawrence Berkeley Laboratory, additional information was obtained from the weapons laboratories and from the Environmental Management Program Office and Idaho National Engineering and Environmental Laboratory, as well as from Lawrence Berkeley National Laboratory. The integration of these inputs formed the basis for this report.

A bibliography of the materials consulted is included at the end of this report.

## **2. Size and Scope of LDRD Program**

Since the early 1990's the Department of Energy multi-program laboratories have managed a growing and increasingly important program of discretionary research under DOE O 413.2. In reviewing the size and scope of the LDRD program, our committee reviewed the 1997 and 1998 LDRD reports to Congress prepared by Defense Programs [11, 10]. The Working Group also reviewed individual LDRD reports prepared by the laboratories and submitted to the DOE headquarters program offices. The Working Group found the reports comprehensive and informative.

Of particular interest is the multiplier effect of the investment on basic scientific research reported. For example, in the FY 1998 Defense Programs LDRD report, LDRD funding supported 703 projects at the three Defense Program laboratories, at a total cost of \$197 million (M). The national security programs provided 71 percent of the funds, yet 97 percent of the LDRD funds were spent on projects affected national security program areas.

The funding for the Office of Science and Environmental Management laboratories is about one-third of the funding at the Defense Program laboratories [10]. At the six Office of Science laboratories, the LDRD program supported 465 projects. The support totaled \$53M, amounting to an average of 3 percent of the SC laboratories' total operating budget, compared to the 6 percent of total operating budget traditionally spent at the Defense Program laboratories. At Lawrence Berkeley National Laboratory, the LDRD budget increased from 1.5 percent to 3.1 percent of total lab operations between

1991 and 1999. The smaller percentage of support for LDRD seems reasonable given that the main business of the Science laboratories is basic scientific research.

At the Idaho National Engineering and Environmental Laboratory, which reports to the Environmental Management Program Office, 87 LDRD projects were supported in 1998, according to the 1998 LDRD report submitted by Defense Programs [10]. The total cost of the projects was \$9.4M. The report indicates that the Environmental Management component of the national security appropriation provided 61 percent of that total. Analysis shows that 82 percent of the LDRD funds at the Idaho National Engineering and Environmental Laboratory were spent on projects that affected national security or environmental management. This again demonstrates the multiplier effect of basic research, i.e., the ability to apply the results of basic scientific research in a number of technical areas.

The research conducted at the National Renewable Energy Laboratory was not specifically covered by DOE O 413.2 and is not treated by the Department as LDRD. That Laboratory reports to the Office of Energy Efficiency and Renewable Energy and has a unique mission within the Department. It has its own Director's Discretionary R&D program. The total funding for their effort averages less than \$4M per year. These funds are not included in the total amount expended by the DOE on LDRD.

For most of the 1990's the LDRD program has provided the multi-program laboratories with their only source of discretionary research funding. At the DOE weapons laboratories with their billion dollar plus operating budgets, LDRD has been at the maximum 6 percent level for several years, providing more than \$50 M annually for research at each of these laboratories. At the Science laboratories, LDRD has been below 4 percent. In all cases, the department has issued and enforced clear management and reporting requirements for this program. The Working Group examined their procedures and reviewed the quality of the research, the level of oversight, and the appropriateness of the funding.

Our review suggests that the action of the Congress last year to cut the LDRD program from 6 percent to 4 percent and to exclude Environmental Management programs from the LDRD base has had particularly serious impacts on the Defense Program laboratories. The Working Group believes that both the national security and the environmental management missions of the Department will be seriously compromised if this action is not reversed.

### **3. Management and Selection Procedures in the LDRD Programs**

Although there are some differences among the Lead Program Secretarial Offices, the LDRD program is administered consistently across the Department, with participation from the headquarters and the area operations offices, the laboratory executive management, and the laboratory technical and administrative staff.

Schematic representations of the project selection process for the SC and the Defense Program laboratories appear in figures 1 and 2. Beginning with an annual strategic planning input from senior laboratory management, the broad outline for the program is vetted with the headquarters lead program secretarial office. The lab LDRD office issues calls for proposals from staff in broad but strategic technical areas, establishes and promulgates review procedures, criteria and committees and then issues and receives the responses.

In Defense Programs the proposed total package is gathered into a Program Plan, which is reviewed by both the headquarters and the area operations office. For Defense Programs, there is an annual on site review of the year's program by the headquarters office. The approved plan then triggers project initiation. Interim and final reports are due annually internally, and the laboratory submits an annual program report to the DOE, which then fashions its annual report to Congress.

The selection processes for Science and Environmental Management laboratories are quite similar. Environmental Management programs at all the laboratories under non-Environmental Program Principal Secretarial Offices were included in the LDRD base before 2000. The resulting LDRD funds were managed as part of the responsible laboratory's process. One distinction in Defense Programs is the existence of the LDRD Working Group, with membership from all three laboratories and the Oakland and Albuquerque operations offices. They coordinate the processes and reviews and ensure consistency of quality across the three laboratories. This group has been functioning for over five years and is a model to emulate.

The perception held by some that the LDRD projects are only casually reviewed before support is awarded and that the laboratory directors view LDRD as their own private "walking around money" could not be further from the truth. Every single LDRD project selected must undergo rigorous peer review from scientists both within and, for large proposals, outside the laboratory.

All three weapons laboratories have struck a good balance between stimulating a sufficiently large number of proposals and controlling the overhead effort required to collect and thoroughly review those submitted. They all use some form of pre-proposal or white paper to identify initial ideas, followed by a significantly smaller number of full proposals that receive the full scrutiny before some are selected for funding. For example, at Lawrence Livermore National Laboratory in FY 1999 there were 590 pre-proposals considered, of which 158 new full proposals were submitted. A total of 89 new projects were selected from among these for funding. At Sandia National Laboratory, New Mexico, for 1999 the corresponding numbers were 718, 214 and 121 for white papers, full proposals and newly funded projects respectively.

These numbers suggest that the average net success rate of proposals is about one in six or seven. This rate seems consistent and reasonable and indicates a careful selection process.

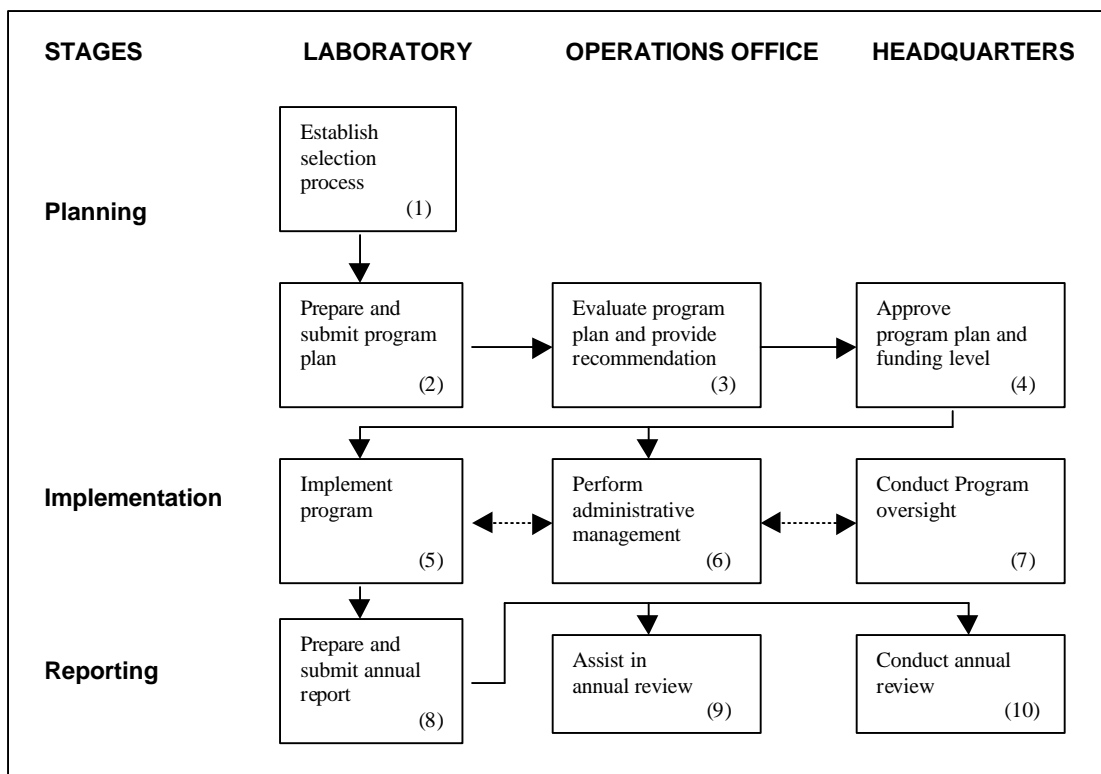


Figure 1. Flowchart of the generic LDRD process in the Office of Science Laboratories

For the Office of Science laboratories, success rates are similar. At Lawrence Berkeley National Laboratory, which uses a one step submission process [no pre-proposals], 45 new proposals and 40 renewals were funded out of 183 submissions in 1999.

It is also important to understand that continuation of a funded project into a second or third year [the maximum allowed] is not automatic. Acceptable progress toward the research goals and milestones must be demonstrated in each yearly review cycle in order for funding to continue. Nevertheless, if the initial selection process has been rigorous follow on funding should be deserved in a majority of the cases. At Sandia in 1998 and 1999 about 95 percent of the requests for second and third year funding were granted. At Lawrence Livermore National Laboratory in the same years the follow on rate was approximately 67 percent. The two laboratories were queried about these differences.

Lawrence Livermore National Laboratory described the continuation decision process as follows: Livermore's LDRD program is 'zero based' each year, with each new and ongoing project being reviewed. Review criteria are quality of idea, quality of research team, progress, and application to the Department's and the Laboratory's missions. A given LDRD project may change its complexion for any one of several reasons including that changes in research results lead to related, but new ideas that get a new LDRD title and tracking code. Others may be moved to another LDRD category such as our



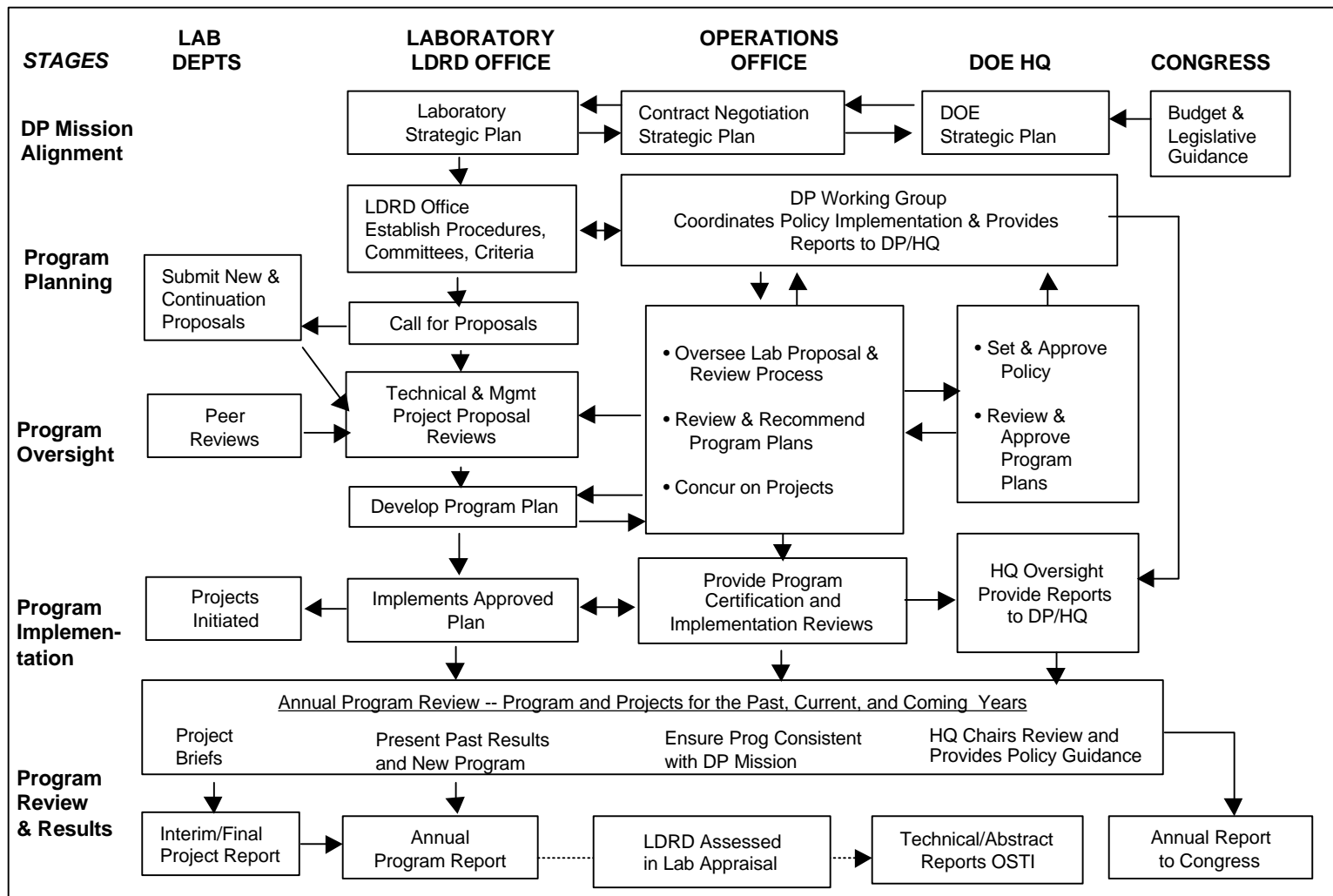


Figure 2. Flowchart of the expanded LDRD process in the Defense Program Laboratories

Strategic Initiative category or the research and development can be so compelling that they are transitioned to programmatic or to outside sponsor-supported work. The Lawrence Livermore National Laboratory management also suggest that LDRD projects are usually high risk in nature, and thus they can fail to meet intentions and are therefore stopped or changed in direction. Finally, a project may be discontinued if the principle investigators leave or change laboratory roles, and new, more important ideas can displace on-going research topics that are proving to be less important.

Sandia, New Mexico, managers replied that the engineering orientation of their laboratory allows a more active on-going management style. They suggested that their LDRD research has a shorter adoption timeframe on average and may be more easily linked to the Lab's mission requirements, allowing for a higher continuation rate than would be expected at the other laboratories. Thus, differences in the continuation rate do not imply any difference in care during the selection process, but rather that there are differences in the laboratory mission that require tailoring the management style to meet the needs of the specific laboratory.

#### **4. Evaluation and Impact**

The Working Group had heard or read charges that LDRD detracted from the programmatic work of the laboratories. We explored this issue with the following results.

At all of the laboratories every project is evaluated annually for its scientific impact through publications and patents, as well as awards. One indicator of the impact of the research is the fact that the LDRD program has earned more R&D 100 awards than any other organization or program in the world. Each laboratory's annual LDRD report provides not only complete data on the size, duration, milestones, and strategic fit but also impact metrics for each project. For example, in 1995 LDRD projects accounted for only 6 percent of the expenditures of the three weapons laboratories but accounted for 40 percent of their refereed publications, 65 percent of the R&D 100 awards and over 30 percent of the patent applications [11].

Fundamental science often yields benefits to technologies quite broadly. This leveraging of the research impact is often referred to as the multiplier effect. Programs that are taxed to support LDRD projects report returns well beyond the fractional support they provide for LDRD.

For example, the largest single source of funding for Sandia National Laboratory, New Mexico, is Defense Programs. Therefore, Defense Programs is the largest contributor to LDRD funding through the percentage assessment on its total operating budget. For FY 1996, 1997, 1998, respectively, the Defense program assessment funded 45, 48 and 48 percent of Sandia's LDRD program. Sandia's program managers determined that the percent of LDRD projects that supported the National Security mission for those same years was 81.6, 86.9 and 90 percent, respectively. Clearly LDRD is not causing the regular laboratory research to suffer as has been charged, but instead is enhancing it

significantly. The two other weapons laboratories have similar analyses and results related to the positive impact of LDRD on programmatic activities.

The list of projects and the approach to assessing impact in the Defense Program laboratories are described in the Department's Annual Report to Congress on LDRD [10]. The report provides a good overview of the scope and distribution of research and development being undertaken in the Department's laboratories.

The Defense Programs LDRD Working Group indicated that the typical staff member who receives LDRD support spends 50 to 75 percent of his/her time on other, programmatic projects. LDRD thus has the very real effect of nucleating and supporting joint projects

In a letter response to questions posed by the LDRD Working Group, Richard Jacobson, Chief Scientist and Deputy Director for research and development, indicated that the Idaho National Engineering and Environmental Laboratory researchers split their time between LDRD and core programmatic funding. Principal investigators, on average, spend approximately 50 percent of their time working on LDRD projects. The Idaho Laboratory LDRD program significantly impacts science and engineering excellence at that Laboratory by delivering research products and bringing national recognition to their research activities and researchers. In the past five years, the combined number of Cooperative Research and Development Agreements, licenses, patents, patent applications and invention disclosures totals 1,170. Of these, 315 or 27 percent have their basis in LDRD. It should be noted that LDRD projects at the Idaho National Engineering and Environmental Laboratory account for about two percent of their operating budget.

In examining the "track record" for successful proposals submitted over the last five years, principal investigators at the Idaho Laboratory reported that 75 percent of their successful proposals were based on work previously supported by LDRD funds. In total, the Idaho Laboratory has received 25 R&D 100 Awards. The Laboratory reports that 23 of the projects were supported by LDRD.

For every laboratory reporting, the Working Group found that the percentage of publications, patents, awards that originated in LDRD projects was far in excess of the 2 to 6 percent of the total laboratory effort that LDRD represents.

On a more anecdotal level, the Working Group queried some laboratory directors for a handful of high impact but representative examples of successful LDRD projects. Their responses included some of the same projects cited by an earlier Department of Energy report, but here are a few additional titles that have contributed significantly to national security: [Their significance is explained in more detail in appendix A for the interested reader.]

### **Sandia National Laboratory**

- CTH & other high performance modeling and simulation codes--started in 1987
- Radiation Hardening Microelectronics—started in 1989
- MicroElectroMechanical Systems-started in 1992
- MUSE-a virtual environment laboratory-started in 1991

### **Los Alamos National Laboratory**

- Propagation of shocks in real materials-CORRTEX started in early 1990's
- Data Transfer Network-invention of HIPPI interface-started in early 1990's
- Universal Behavior of Nonlinear Systems- started in the 1970's
- Proton Radiography-first demonstrated in 1997

### **Lawrence Livermore National Laboratory**

- Parallel Processing Computing Architectures-basis for ASCI-started in early 1990's
- Pu equations of state surprises using laser heated diamond anvil cells-started in 1991
- Sub picosecond laser cutter for disassembly
- US most advanced bio-pathogen detectors

### **Idaho National Engineering and Environmental Laboratory**

Surfactant-Enhanced Aquifer Remediation at Neutral Buoyancy (SEAR-NB)  
Decontamination, Decommissioning, and Remediation Optimal Planning System (DDROPS)

In 1992, the Department of Energy conducted an assessment of the LDRD program and its predecessor ERD. The findings were issued in a report titled *Measuring Investment in R&D Excellence: A Study of Laboratory Directed Research and Development at the Nine DOE Multiprogram Laboratories*. The report concluded that the LDRD projects generated substantial intellectual property and that LDRD enhanced “the vitality and flexibility of the laboratories” and provided “scientific and technical benefits that accrue to the laboratories, to the Department, and to the nation...” This study examined over 3,000 projects spread among the weapons and the then Energy Research laboratories. [7]

A more comprehensive list of high impact LDRD projects is included in the 1997 study of LDRD, *Innovation and Creativity Supporting National Security* [11]. This list illustrates the widespread and multiplying impact of LDRD on mission accomplishment.

Without exception the laboratories' management expressed enthusiasm for the value and positive leverage that LDRD has on the quality of science, the morale of staff, the ability to hire outstanding people, reputation of the laboratory, and the quality of direct mission oriented programs.

## **5. Comparisons with Industry**

In order to establish what might be considered a reasonable proportion of support for basic research as a fraction of total research and development, the Working Group sought information on current and historical industry practices. Research and Development

generally covers the spectrum from basic through applied research to exploratory through product development. Research is often used to cover both basic and applied research. The Working Group views LDRD as rather basic research, with some overlap with applied research. All organizations struggle with achieving the appropriate balance between research and development. Benchmarking with competitors and similar companies is a standard method used in industry to address this issue. Some findings are reported below.

Craig Fields, in the Defense Science Board Task Force Report, *The Defense Science and Technology Base for the 21<sup>st</sup> Century* [5], quotes Industrial Research Institute figures. He notes that high technology enterprises like pharmaceuticals and information companies are spending 16 percent of revenues on research and development and 3.4 percent on research, for a ratio of 4:1. For comparison, we note that Lucent Technologies today spends 11 percent of revenues on research and development and 1 percent on research, for a 10:1 ratio--about the historic level at Bell Laboratories. The 1982 Packard Report [26] concluded that setting research at 10 percent of research and development was about right.

According to data from the National Science Foundation provided to the Working Group by Chuck Larson, Executive Director of the Industrial Research Institute, in 1999, \$168 billion (B) will be spent on research and development with \$11B for basic research, \$39B for applied research and \$118B on development industry wide. The conservative interpretation of this data is that 11/168 or 7 percent is spent on research; the liberal interpretation is that 50/168 or 30 percent is spent on research. This is closer to the Department of Defense number quoted by Fields [5]. By any of these measures, a figure of 6 percent, the former LDRD level, appears conservative for an organization with product and systems delivery responsibility. A figure of 4 percent is clearly well below threshold.

As part of our assessment of best practices in industry, the Laboratory Operations Board Working Group, which was composed of former research leaders at IBM [John Armstrong], DuPont [Al McLachlan], Ford [John McTague], and Bell Laboratories [Paul Fleury] conducted an informal survey of their respective companies. There was uniform recognition among these high-tech corporate research and development organizations of the need for “well-informed flexibility in executing long-range, underpinning-type research.”

At Lucent Technologies, specifics include a fully corporate funded research organization, a ratio of about 10:1 in development to research, and the institution and operation of so-called “breakthrough projects,” which are strategically and formally agreed-upon by the executive management of both central research and the relevant business units. The methods of tracking the progress and the impact of such breakthrough projects have been increasingly refined at Lucent over the past few years. Nevertheless, neither the level of management detail nor the adherence to numerical impact metrics is as detailed as in the Department of Energy’s LDRD program.

The experiences and practices at IBM, DuPont, and Ford, are quite similar in motivation and spirit, if not in detail of execution. Further, all industrial laboratories recognize the importance of having staff who can “impedance match” to the larger outside world of science and allow for “fast following” as well as prevention of “blindsiding.” LDRD enables the laboratories to do this too. Al MacLachlan had compared research and development practices at several of the major industrial firms. The Department of Energy’s report, *Corporate R&D in Transition* [6], also examined recent trends (1996).

This conclusion is strengthened by the observation that high-tech industrial laboratories are able to profit from a large quantity of open, published work that is done in the universities and in other companies. This 'large world' effect applies much less strongly to defense laboratories, since there are many fewer such laboratories, and there is (understandably) much less openness with results. This suggests that defense laboratories may need to spend a larger proportion of their budgets on exploratory work than is necessary in private industry.

From these documents, discussions, interviews and comparisons, the Working Group concludes the following regarding the philosophy and management of LDRD:

- (1) the identification of key strategic research areas underpinning the laboratory missions involves an appropriate level of laboratory and Department of Energy executives,

- (2) appropriate processes for the call for proposals and the evaluation of proposals, both for scientific quality and programmatic relevance are in place,

- (3) the process internal to the laboratories for evaluating the progress and outcomes of each project are in place,

- (4) metrics for the projects’ scientific and programmatic impact, as well as follow-on funding, are in place,

- (5) the level of LDRD at 6 percent is below the industry average for the research/development ratio in high technology industries. The 4 percent level fails any reasonable comparison test.

## **6. Criticisms of Laboratory Directed Research and Development**

The positive evidence of the high impact and critical importance of the LDRD program notwithstanding, there continue to be attacks on the philosophy and the execution of the program. The size of the program, nearly \$300 million in FY 1999, and the absence of direct congressional control over its individual projects appear largely responsible for this scrutiny. However, the overall size amounts to less than what any one of several industrial firms spends on its own in-house research, and as discussed above, LDRD projects receive even more reviews.

Over the past decade, LDRD or similar programs at Los Alamos National Laboratory (1989) [14], Lawrence Livermore National Laboratory (1997) [16], National Renewable Energy Laboratory (1998) [22], Princeton Physics Laboratory (1989) [13], and the Idaho National Engineering and Environmental Laboratory (1998) [20] have received scrutiny and negative reports from either the Office of the Inspector General or the Office of Management and Budget. In every case the Laboratories have responded fully to the

negative characterizations in the Office of the Inspector General reviews. In many cases there have been factual or fairly obvious interpretation differences between the laboratory and the Office of the Inspector General. In no cases have the laboratories fully concurred with allegations of mismanagement of discretionary research funds.

However, even if all of the allegations in all of the reports issued over the past decade were accurate, the fraction of the total discretionary funding in question is of the order of one percent of the total LDRD spending since 1989. It is seriously doubtful whether the amounts in question come anywhere near the amounts expended in these investigations. Obviously, no complex program of any kind can be absolutely free of errors or some occasional instances of poor management. From a cost/benefit point of view, the repeated fruitless investigations of LDRD that have occurred over the past several years appears to have passed the point of diminishing returns.

## **7. Recent Trends and Consequences**

### **Impacts on Mission**

The action of Congress last year to cut the LDRD program back from 6 percent to 4 percent had a particularly serious impact on the Defense Program laboratories. The action threatens the National Defense mission of the Department of Energy seriously in ways that are articulated below.

The impact of excluding Environmental Management funds from LDRD has been severe for the Idaho National Engineering and Environmental Laboratory and in fact for all the laboratories that perform work for Environmental Management. The serious consequences of the exclusion are on the environmental cleanup mission of the department, which will be compromised by this exclusion. For many years the responsibility for clean up at the Department of Energy has been interpreted as being limited to intense and diligent application of known technologies and processes to the remediation requirement. The Department has been spending more on these efforts than on its nuclear weapons mission for some time. Yet there has been very little research on new approaches to the clean up challenge, especially at the basic science level.

Environmental Management Science Programs comes the closest within Environmental Management to running a research program, but Environmental Management Science Programs does not generally fund early stage or proof of concept research. In effect as far as the science base for the clean up mission is concerned, LDRD has been the only flexible source of such research. The zeroing out of Environmental Management support for LDRD at both the Idaho National Engineering and Environmental Laboratory and all of the other Department of Energy laboratories undermines the long-term prospects for new and more successful approaches to the clean up mission.

The combined effects of the 6 percent to 4 percent reductions and the elimination of Environmental Management programs from the LDRD base has eliminated over \$100M

in flexible research funding from the Department's laboratory system in FY 2000. This is a reduction of nearly 40 percent in a single year in one of the most important programs for the future of the laboratories. The Working Group believes that both the national security and the environmental management missions of the Department will be seriously compromised if these recent legislative actions are not reversed.

The current version of the LDRD program was initiated in the early 1990's with DOE Order 5000.4A. In the intervening decade the effects of the end of the cold war, emergence of sharpened nuclear proliferation concerns, and the de facto end of nuclear weapons testing have dramatically altered the landscape for weapons Research and Development. Other factors such as the increasing globalization of science and commerce, and the continued decline in the numbers of United States students pursuing graduate education in science and engineering have affected both the Science and the Weapons laboratories.

Over this same period there has been a significant decline in the "weapons supporting research" budgets of all three weapons laboratories. Figure 3 shows the trend for Lawrence Livermore Laboratory. Until the middle of the last decade, the Defense Program laboratories had used about 15 percent of their funds for research-related activities. A formalized process for setting aside research and development funds and allowing them to be used across laboratory programs was formulated (i.e., LDRD) by the Department of Energy and the laboratories. In spite of these efforts, today they spend less than 8 to 10 percent total on research and early development, including the 6 percent that has formally been allocated to LDRD. Today, LDRD funds provide virtually all of the laboratories' basic research support and almost all new-concept development work. From the 1960s through the 1980s, other discretionary funds were available to laboratory programs.

Weapons supporting research funds were used successfully to support a vast number of basic scientific and engineering developments in computation physics, materials, equation-of-state, radiation transport, and many others for the weapons program. However, this funding mechanism became increasingly focused on programmatic problems, and is no longer available. LDRD has provided support for important research and development, but many in the laboratories feel that it can not support all of the advanced research and development needed to keep them healthy and as able to deliver on their missions as effectively in the long term as they had been. The net effect of these and other trends has been to increase the dependence upon a strong science base at all the Department's laboratories in order to achieve their respective missions, at the very time when support for this science base has been eroded.

Perhaps the major national response to the end of nuclear testing has been the initiation of the Science Based Stockpile Stewardship Program. The goal is to increase the understanding of nuclear weapons and supporting systems. The increase must reach the point at which a combination of allowed components testing and sophisticated computer



## WSR plus LDRD from FY77-FY00 as a percent of LLNL operating budget

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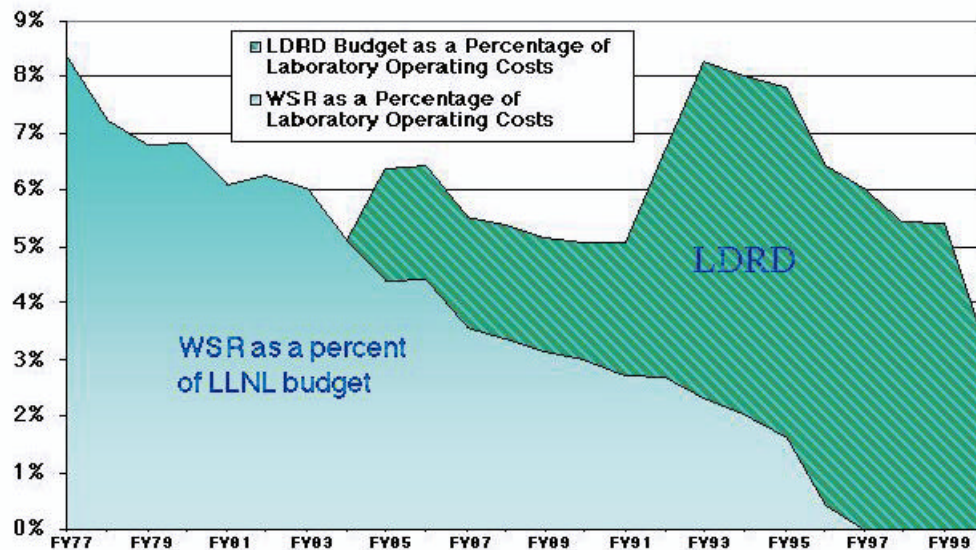


Figure 3. Weapons Supported Research plus LDRD

modeling and simulation can provide confidence in the safety, security, reliability and use control of the nuclear weapons stockpile at least equal to that previously provided by testing

The concomitant benefits to society as a whole--well beyond the weapons program—could be enormous. The importance of this increased understanding is unquestioned, but it is the end of testing, the aging of the stockpile and the aging of the weapons designer population that have provided the urgency for implementing the Science Based Stockpile Stewardship Program. Precisely because the goal is so challenging and so dependent on advances in science, the importance to the national security of continued substantial investment in the Laboratories' science base is greater than ever.

### Impact on Scientific Talent

Although the direct impacts on LDRD funding cuts have differed among the different categories of laboratory, uncertainty in the climate and congressional attitude toward continued investment in the science base at all the laboratories has begun to affect their ability to attract and retain the best talent. Maintaining the talent pool at the laboratories has always been a challenge, but in today's ultra competitive job market the laboratories' ability to compete for talent with private industry and the best universities is particularly at risk.

Data on distribution of LDRD projects among the divisions within the weapons laboratories show, together with the information presented above, the following. (a) New hires, especially postdoctorates are supported disproportionately by LDRD. For example, at Los Alamos National Laboratory over 50 percent of their nearly 400 postdoctorates have some LDRD support, and from 25 to 30 percent of those go on to become permanent laboratory staff. The postdoctoral program allows the laboratory to select the very best candidates for offers of permanent positions. (b) There has been a decrease in the laboratories' ability to recruit and retain the best scientific talent. (c) A typical staff member receiving LDRD support typically works 75 percent of his time on programmatic projects simultaneously, so a combination of basic and directed projects are addressed. (d) A strongly disproportionate number of the laboratories' publications, patents, awards and recognition come from LDRD projects. (e) The benefit to defense projects is well in excess of the Defense Programs' LDRD investment.

At Lawrence Livermore National Laboratory between 1993 and 1998, 41 percent of LDRD funded postdoctorates were subsequently hired by the Laboratory; 57 percent of all their postdoctorates were supported at least in part by LDRD. For 1993 through 1998, 65 percent of LDRD postdoctorates supported National Security Activities.

At Los Alamos for most of the 1990's, 40 to 50 percent of the total postdoctoral employees (total of 400) participated in LDRD projects. Each year nearly 40 percent of postdoctoral employees are hired into staff positions at Los Alamos (160 total, nearly half from LDRD postdoctoral ranks). The Sandia total postdoctoral program is smaller than those in the University of California managed laboratories, but LDRD experience figures prominently into their hiring program as well.

Similar concerns regarding personnel are emerging at the science laboratories as well. This is because the national interest in terms of workforce for innovation and the source for new ideas is likely to be severely compromised throughout the laboratories in today's recruiting environment.

A related negative impact of the decrease in research-oriented activities and the loss of the more research-oriented personnel is a reduction in the laboratories' abilities to collaborate with and take advantage of university talent. At the laboratories--as with industrial research and development enterprises--a significant in-house effort on basic, non-programmatic research conducted by talented and active members of the worldwide research community provides direct benefits to the organization in terms of new discoveries and inventions. It also provides opportunities for bona fide membership by the in-house researchers in the larger community with access to the activities and discoveries of others not available otherwise.

In the process of creating the National Nuclear Security Administration, positive measures should be taken to ensure that the new interdepartmental administrative procedures affecting the defense laboratories will enable their continued effective support of the science as well as the defense mission of the agency. If at all possible, the Department must avoid fragmentation or compartmentalization of the LDRD program so

that the Defense Programs projects continue to benefit from laboratory-wide research advances. Fragmentation or compartmentalization would have an adverse effect generally throughout the Department and its Laboratories by reducing the opportunity for all scientists to engage in collaborations on scientific research projects.

## **8. Findings and Recommendations**

The Working Group's findings are listed below. Based on the findings, the Working Group has developed recommendations directed at both the Department and the Congress.

The Working Group finds that

- The need and concept for the LDRD program is sound and congruent with industry best practices.
- LDRD type programs have historically enabled the Department to prepare for future mission responsibilities.
- LDRD programs are vital in recruiting, retaining and integrating the best scientific talent into the laboratories and their mission programs.
- LDRD programs are the most effective of all departmental programs in generating scientific discoveries, patents, publications and awards.
- The size of the LDRD program at a 6 percent maximum is sound and consistent with the low end of overall industry practices. The 6 percent level as a fraction of total research and development is substantially below average for high tech industry.
- The LDRD program is generally well managed, but some variation exists among the different responsible Secretarial Offices. Considerable review and oversight is in place at the laboratory, field office, and headquarters levels. Indeed the process is more complex than is typical in industry.
- Accusations of mismanagement instances are relatively few in number and have not, in any serious way, detracted from the need for, or the performance of a strong and continuing LDRD program.
- Flexible research programs like LDRD are important to all of the multi program laboratories, but are especially critical for the weapons laboratories because of the unique role of LDRD in sustaining the science base.
- The present cuts in LDRD at the weapons laboratories constitute a threat to national security by curtailing the laboratories' science base research, reducing the incentive for the best scientists to join and/or remain at the laboratories, and

decoupling the weapons laboratories from the much larger scientific community worldwide.

- The elimination of Environmental Management's programs from the LDRD funding base has weakened the nation's effort at clean up by reducing the science base needed for discovery of novel and qualitatively different approaches to the clean up challenge.

- The proposed reorganization of the Department of Energy to establish a semi-autonomous National Nuclear Security Administration could threaten the quality and collaborative nature of the science base at the weapons laboratories.

Based on these findings the Working Group recommends that

- The Congress should restore the LDRD program at the DOE multi-program laboratories to at least 6 percent, and should restore Environmental Management programs to the LDRD base.

- The Department should simplify LDRD oversight and approval process to be more consistent across the Department and with industry best practices.

- In the design and implementation of the proposed DOE reorganization, careful consideration should be given to ensuring continued support for the defense science base and the continued ability of the LDRD program to serve all aspects of the laboratories' programs.

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# **Appendix A**

## **High Impact LDRD Projects**

The three Defense Program laboratories were asked to identify at least three significant projects that had been funded initially by LDRD or other discretionary research funds during the last 5 to 10 years. By significant, the intent was to identify projects that had had a significant impact on the mission of the laboratory, particularly in their defense related work. In addition, the Idaho National Engineering and Environmental Laboratory (INEEL) was asked and provided a list of significant projects initiated with LDRD funds. The laboratories provided the following information in response to this request.

### **SANDIA NATIONAL LABORATORY**

#### **CTH (and other high-performance modeling and simulation codes)**

Time Frame: Initial components' research and developments began in 1987 and have continued through the 1990s.

Research: Develop fast, efficient, and effective 3-D automatic meshing techniques. Develop techniques for predicting particle size distributions from dynamic fragmentation events.

Accomplishments: Various research capabilities were integrated to create the CTH code. CTH is a multi-material, large deformation, strong shock wave, solid mechanics code that is used for analyzing problems involving intense, impulsive loading of materials and structures.

National Security and DOE Defense Programs (DP) Impact: CTH models the dynamic mechanical response of a number of advanced materials that are used in nuclear weapons systems. For example, CTH can be used to model the carbon-phenolic composite material that is used in the aeroshell of ballistic missiles. Another application is the modeling of the polar ferroelectric materials that are found in shock-actuated power supplies for some weapon components.

CTH also incorporates capabilities for modeling dynamic fragmentation events and determining average fragment size. This has been used in defense-related applications such as formation of fragments in explosive accidents involving non-nuclear detonation of warheads, destruction of conventional explosive weapons and debris formation during high-velocity impact.

#### **Radiation Hardening of Microelectronics**

Time Frame: Radiation effects have been researched at Sandia for decades. Radiation hardening research of devices has been a significant focus for the last ten years.

Research: Investigate Single Event Effects (SEE) as the result of high-energy nuclear particles (e.g. cosmic rays) impacting upon, and disrupting or disabling a microelectronic

device. Advances in understanding this problem are especially important since SEE becomes increasingly probable as integrated circuit feature size decreases. For example, current 0.25 micron feature size ICs sometimes fail in terrestrial applications. In addition, LDRD research has also focused upon designing radiation hardened robots. Rad-hard robotics research has focused upon three areas: predicting radiation doses, hardening to radiation, and monitoring doses during operation.

Accomplishments: Sandia has developed three forms of radiation effects microscopy (in conjunction with Labs' modeling and simulation capabilities) to measure SEE in situ. Single Event Upset (SEU) Imaging allows in situ observations of the location of upset (data loss) events in working ICs as a function of operating parameters. Ion Beam-Induced Charge Collection (IBICC) maps the charge generated in an IC when a high-energy heavy ion strikes. The IBICC map helps identify charge movement that can lead to loss of data, or loss of device function. The time-resolved version of IBICC maps the effects of temporal effects of SEE in order to validate 3-D models.

National Security and DP Impact: Radiation effects microscopy has provided a means for validating stockpile microelectronics reliability. This capability has greatly reduced development costs for stockpile microelectronics. In addition, the design of radiation-hardened robots has had a significant impact on applications such as nuclear waste cleanup, nuclear plant maintenance, decontamination and decommissioning, and emergency response.

## **MEMS (MicroElectroMechanical Systems)**

Time Frame: Initiated by LDRD funding in 1992, Sandia's MEMS technology has become the national standard for how microsystems are built.

Research and Accomplishments: Sandia research has developed processes to make surface machined silicon and LIGA (Lithographie Galvanoformung Abformung) parts with 100 micron outside dimensions and submicron tolerances for use in weapons surety devices. LIGA parts are of special interest because they are thicker than typical surface machined parts; they can be made of metals, which makes them stronger (in tension) than surface machined silicon.

LDRD research has developed a set of standardized MEMS components that can all be fabricated in Sandia's multilevel polysilicon surface-micromachining process. These standard parts will help improve the design of MEMS' devices since most design are characterized by a trial-and-error approach that results in several iterated fabrication runs before achieving functional devices.

In addition, the results of various recent MEMS LDRD research (e.g., Standardized components; Vacuum encapsulation of MEMS structures; Agile prototyping of MEMS; and Reliability Test Structures, etc.) is being incorporated into the TSSC (Trajectory Sensing System on a Chip) device. The TSSC device is the most complex and ambitious microsystem that DOE DP has attempted.

National Security and DP Impact: The MEMS technology has matured and will have a significant impact on weapons systems, particularly the W80 and the W76.

## **MUSE (A Virtual Environment Laboratory)**

Time Frame: Began in 1991 and some enhancements through mid-1990s.

Research: Develop 3-D virtual reality engine for real-time observation of complex designs, simulations and data fusions.

Accomplishments: Developed and patented MUSE, a virtual 3-D environment that allows engineers to identify anomalies in designs, data fusions and simulations.

National Security and DP Impact: Developed as a model-based design and virtual test environment and incorporated into Sandia's Weapons Engineering Product Realization Environment (WEPRE) Facility. WEPRE provides state-of-the-art capabilities to visualize, enhance, manipulate, and interpret weapon design information. MUSE has also been useful for various non-proliferation data fusion applications.

## **LOS ALAMOS NATIONAL LABORATORY**

### **Propagation of Shocks in Real Materials**

Time frame: 1989-1991

Research: The development of a technique for on-site verification and measurement of nuclear weapons yield.

Accomplishments: Based on a detailed understanding of the propagation of shock waves in real materials, a technique called Continuous Reflectivity Radius versus Time Experiment (CORRTEX) was developed. In addition, LANL demonstrated the method developed at the Nevada test site was applicable to the different geologic conditions in Russia.

National Security and DP Impact: The LDRD-funded work, which demonstrated transferability of the CORRTEX technique, played a major role in establishing a framework of trust for the successful and prompt conclusion of the threshold test ban treaty. This ultimately resulted in a moratorium on nuclear testing and fundamentally changed the approach taken by DOE Defense Programs to nuclear weapons stockpile stewardship.

### **Data Transfer Network**

Timeframe: 1988-1990, with additional work in 1991-1993.

Research: Developing a high-performance parallel interface (HIPPI).

Accomplishments: Researchers advanced the state of the art in fast, data-transfer network technology, providing local networks with data transfer rates of 800 million bits per second. HIPPI became the high-speed interface of choice for supercomputers in the 90's, in effect providing the "upgrade path" for much of supercomputing in the whole U.S. information economy.

National Security and DP Impact: Enabled computer simulations of nuclear weapons, which requires not only the most powerful computers available but also the ability to transfer huge amounts of computational data and the capability to display this data in forms that can be more easily digested and analyzed.

## **Universal Behavior in Nonlinear Systems**

Timeframe: 1978 to 1980

Research: Theoretical investigation behavior in nonlinear systems.

Accomplishments: Discovery of universal behavior in nonlinear systems, which effects theoretical approaches to problems ranging from quantum physics to economics. hydrodynamics directly relevant to weapons physics. The fertile environment created by fundamental discoveries in nonlinear science has lead to creative advances in hydrodynamic modeling that are now embodied in weapons simulation codes.

National Security and DP Impact: Los Alamos revitalized its research on turbulence and hydrodynamics directly relevant to weapons physics. The fertile environment created by fundamental discoveries in nonlinear science has lead to creative advances in hydrodynamic modeling that are now embodied in weapons simulation codes.

## **Proton Radiography**

Timeframe: 1996, with follow-on project from 1997 to 1999

Research: Investigation of novel radiographic tools.

Accomplishments: Demonstrated the feasibility of using protons for radiography. Specifically, examined a detonation wave from a small explosion.

National Security and DP Impact: First, the technology has already affected real, nontrivial, decisions about the nation's enduring stockpile. Second, the technique has become a key (perhaps the key) element in the long-term approach LANL expects to take to hydro-radiography. It would not be far from the truth to say that LANL is betting its institutional future, and the ultimate success of Stockpile Stewardship, on this LDRD result.

## **LAWRENCE LIVERMORE NATIONAL LABORATORY**

### **Parallel Processing Computer Architectures**

Time Frame: From 1987 to the present, LDRD funded research on techniques for optimal architectures and numerical problem solving on massively parallel computers for scientific simulations.

Research: LDRD has invested substantial resources to bring the first massively parallel computers to the Lawrence Livermore National Laboratory. It has supported the investigation of shared memory architecture and the development of system software. LDRD continues today to support “scalable” algorithm and visualization R&D to enable 3-D and other complex problem solving.

Results: Early LDRD sponsored research demonstrated that massively-parallel computers would provide an efficient and cost-effective platform for large-scale scientific applications. Subsequent LDRD projects addressed critical problems related to nuclear

weapons simulation methods, storage and transfer of large amounts of data, and the visualization and interpretation of large three-dimensional data sets.

Impact on Laboratory Mission: These far-sighted investments laid the foundations that have made ASCI possible.

### **Pu Equations-of-State Surprises using Laser-Heated Diamond Anvil Cells**

Time Frame: From the late 1980s through the 1990s, LDRD funds have been used to develop the technology to use diamond anvil cells for geophysical and EOS research at LLNL.

Research: In the early 1990s, LDRD sponsored a project to study materials under both high pressure and high temperature, using a diamond anvil cell to create high pressures and a laser to heat the material to high temperature. The technology was applied to materials of fundamental and applied interest to LLNL defense programs.

Results: It is now possible to measure the equations of state and the melting properties of metals and other materials in regimes that previously could only be reached during chemical or nuclear explosion driven experiments.

Impact on Laboratory Mission: The melting curve of Pu, obtained by LDRD sponsored research, has proven to be of great interest for stockpile stewardship. It is now possible to simulate the distribution of solids and liquids in dynamic devices and so predict their performance. This has changed our understanding of the behavior of primaries in nuclear explosives.

### **Sub-Picosecond Laser Cutter for Disassembly**

Time Frame: In the late 1980s through the 1990s, LDRD sponsored projects to develop pico-second and femto-second lasers for atomic physics and laser materials R&D.

Research: LDRD funds were used through the 1990s, in a series of differently oriented projects, to understand the interaction of short pulse lasers with materials. Two topics were emphasized: femto-second laser cutting and “fast igniter” fusion.

Results: A new régime of laser solid interaction was discovered, called “heatless” cutting. In the femto-second regime, the laser heats atoms and molecules so rapidly that there is not time for heat to be transported by phonons or electrons. Several major publications and patents issued. Secondly, technological methods to generate significant energy, and consequently very high power in femto-second pulse regimes, were developed and demonstrated with a “Petawatt” laser and target experiments, piggybacked on the Nova Laser. .

Impact on Laboratory Mission: Outcomes of this research include two program-funded short-pulse, high-powered lasers for machining applications. One is to remanufacture weapons systems in an environmentally benign and cost-effective manner. Such a system has been delivered to DOE’s Y-12. The second is an aerospace sponsored system for drilling long, straight holes in refractory metals economically. Finally, very high power applications, e.g.,  $10^{15}$  W or petawatts of power, have led to new defense program applications in inertial fusion and radiography.

## **U. S.'s Most Advanced Bio-Pathogen Detectors**

Time Frame: Throughout the 1990s, LDRD has sponsored research topics on the development of bio-detectors and their applications to the detection of bio-pathogens for DOE and other agency missions.

Research: LDRD funds were used to develop miniaturized polymerase chain reaction (PCR) chambers and flow cytometers.

Results: In the case of a terrorist attack or on a battlefield, it is important to determine if a biological agent has been used and, if so, to identify it quickly. LDRD successfully developed two highly portable, extremely sensitive, and very reliable technologies. One uses PCR replication of trace amounts of nucleotides and the other uses florescent tagging of cells. These technologies have been tested by the Army at Dugway Proving Ground in Utah along with a number of competing technologies and were found to be superior in all ways.

Impact on Laboratory Mission: The nation recognizes its vulnerability to bio-terrorism and the use of biological weapons. Because of this and other LDRD sponsored projects, the Laboratory and DOE have demonstrated technological capabilities that have become one of the major techniques to counter such threats.

## **IDAHO NATIONAL ENGINEERING AND ENVIRONMENTAL LABORATORY**

### **Surfactant-Enhanced Aquifer Remediation at Neutral Buoyancy (SEAR-NB)**

Time Frame: The LDRD program funded proof of concept testing in FY94. The technology has since been enhanced through direct EM funds.

Research and Accomplishments: In SEAR-NB, environmentally friendly surfactants are injected into a DNAPL-contaminated zone through a groundwater well to increase aqueous solubility and mobilize the contamination plume. The plume moves toward other wells used to extract the contaminant. The technology uses inspectional analysis and 2-D modeling to accurately predict the vertical migration of the plume. Injection rate, phase density, phase viscosity and well spacing are manipulated to affect plume migration – and prevent it from being driven deeper into the aquifer. This technology has been demonstrated, and an EPA site is slated to have the process running in the summer of 2000.

LDRD funding allowed researchers to do proof-of-concept, suggesting that this technology could successfully remediate DNAPLs under conditions previous thought impossible. That demonstration convinced DOE to provide additional funding to further develop the technology. As a result, an Environmental Protection Agency site is slated to have the process running in the summer of 2000.

Environment and EM Impact: Worldwide, an estimated 300,000 sites are contaminated with chlorinated solvents – dense, non-aqueous phase liquids (DNAPLs) that are difficult to remove from the environment. DNAPLs are denser than surrounding groundwater and can migrate below the water table to contaminate aquifers – becoming a long-term polluter of future water supplies. The SEAR-NB process provides orders of magnitude improvements in cleanup time and cost over the only other technology used in this environment – pump and treat.

## **Decontamination, Decommissioning, and Remediation Optimal Planning System (DDROPS)**

Time Frame: This computer program has been developed entirely on LDRD funding from FY97 through FY98.

Research and Accomplishments: The simulation process begins by building a computer-generated model of the facility using existing Computer-Aided Design (CAD) files, blueprints, as-built drawings, photographs, laser scanning, and manual techniques. Information such as radiation levels, materials composition, or weight can also be included. The resulting model uses algorithms to determine the best locations for making necessary cuts to remove components such as pipes, valves, and tanks, and portrays the information as both two- and three-dimensional representations. Using the computer to model cutting geometry is more efficient and eliminates the need for workers to make additional cuts once the equipment is out of the building and being loaded into waste boxes.

LDRD funds were used for the development of this unique software program – linking, for the first time, a traditional CAD package with optimization software and radiation field data. The primary benefits of the research are the ability to do risk-free decommissioning planning, reduce actual decommissioning deployment costs, and improve worker safety. The software program is now a licensable product.

Environment and EM Impact: The DOE has identified over 7000 contaminated facilities that must be decommissioned. The price tag for accomplishing this task using current technologies has been estimated to be in excess of \$60 billion. DDROPS is a simulation software program that allows facility managers to simulate a facility and conduct remediation planning for waste minimization purposes and to minimize the exposure of workers to hazards.





## **APPENDIX C**

### **LABORATORY OPERATIONS BOARD TERMS OF REFERENCE**

#### **Purpose**

The Laboratory Operations Board's fundamental goal is to help facilitate productive and cost-effective utilization of the Department of Energy's laboratory system. The Board will assist the Department in bringing sharpened focus to the missions of the laboratories and ensuring speedy resolution of issues and problems across the integrated laboratory system.

The Board is to provide advice regarding the strategic direction for the Department's laboratory system, the coordination of budget and policy issues affecting laboratory operations, and the reduction of unnecessary and counterproductive management burdens on the laboratories.

The Board will facilitate application of best business practices in management of the laboratories and will develop recommendations for the Secretary regarding changes in the size, missions, and scope of laboratory activities in light of changes in federal funding. The principle focus of the Board will be on the Department's multi-program laboratories and major program-dedicated laboratories.

The Laboratory Operations Board shall be constituted as a subcommittee of the Secretary of Energy Advisory Board and shall report to the Secretary of Energy Advisory Board.

#### **Membership**

Total membership of the Board will be twenty-two. Of the twenty-two, thirteen will represent the Department and nine will be external members. The Laboratory Operations Board shall be co-chaired by the Under Secretary of Energy and an external member selected by the Secretary.

##### [Department Representatives](#)

The Department will be represented on the Laboratory Operations Board by the relevant program offices, those offices with administrative and management responsibilities for the laboratories and from those areas responsible for operation of the laboratories. In addition there will be departmental representatives who rotate on an annual basis. Two members representing the laboratory directors, one member representing the field managers and three members selected from designated advisors to the Laboratory Operations Board. The Co-Chairs of the Laboratory Operations Board will be responsible for designating new members.

### External Representatives

The external representation will be made up of nine advisors selected for their experiences and accomplishments in academia, industry, or government. The external advisors shall have staggered, six year terms to provide continuity through changes of Presidential administrations. An external advisor will serve as co-chairman.

#### Board Composition:

Under Secretary, Co-Chair  
External Member, Co-Chair

8 Additional External members

Assistant Secretary for Defense Programs  
Director, Office of Energy Research  
Assistant Secretary for Energy Efficiency and Renewable Energy  
Assistant Secretary for Environmental Management  
Assistant Secretary for Fossil Energy  
Director of Field Management  
Laboratory Directors (2 rotating members - one year terms)  
Field Manager (1 rotating member - one year term)  
3 Rotating Advisory Members (one year terms)

#### List of potential Rotating Advisory Members:

General Counsel  
Chief Financial Officer  
Procurement Officer  
Assistant Secretary for Human Resources  
Assistant Secretary for Environment, Safety and Health  
Assistant Secretary for Policy, Planning and Program Evaluation  
Director, Office of Nuclear Energy

### **Roles/Responsibilities**

Each member of the Board will be responsible for providing individual advice and recommendations with regard to:

- Strategic direction for the laboratories including validation of strategic plans, tracking of cross-cutting programmatic and management issues, and monitoring of coordination of the laboratories as a system;
- Ensuring application of best practices and addressing resource impacts of administrative and regulatory requirements;
- Efforts by the Department to enhance integration among its basic and applied research programs and between the laboratory system and other research and development performers in academia, industry and other government agencies.

In addition, External Members' roles and responsibilities include the following:

As requested, review and provide comments related to the Department's budget for programs performed within the Department's laboratory system to the Under Secretary.

Conduct analyses of issues and programs involving the Department's laboratories. Such studies will be conducted under the auspices of the Secretary of Energy Advisory Board and provide the basis for independent recommendations formulated by the External Members of the Laboratory Operations Board.

Provide at least semi-annual letter reports to the Secretary, through the Secretary of Energy Advisory Board. Such reports should assess progress by the Department and the laboratories in meeting goals in areas such as management initiatives, productivity improvement, mission focus and programmatic accomplishments.

### **Subcommittees**

Subcommittees of the Board may be established as appropriate to address specific issues. Subcommittees are to include the following:

External Members Subcommittee:

The nine external members of the Board shall serve as a subcommittee of the Laboratory Operations Board. This subcommittee is authorized to perform separate duties as specified in the section on Roles/ Responsibilities and to report directly to the Secretary of Energy Advisory Board.

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*March 25, 1998*



